

FOTOFAB



DESIGN GUIDE

TO PHOTOCHEMICAL MACHINING

Let's walk you through the photochemical machining (PCM), or chemical etching, process and its benefits. We will share exactly how Fotofab delivers precision metal parts for your critical tolerance application.

We will cover:

- The engineering advantages and manufacturing steps
- Types of metals we etch
- Design considerations for your project and application
- Products and finishing options

FOTOFAB

If you still have questions, we are here to walk you through from rapid prototyping to full-scale production.

We look forward to being **A Part In Your Plan.**

Sincerely,

Charles Cohen

President, Fotofab



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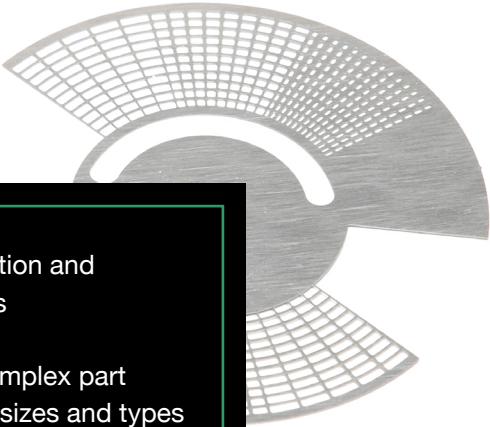
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Introduction & Advantages

Our photochemical etching process uses a Ferric Chloride acid to remove selected metal, creating a design or image formed to your project's exact specifications. PCM provides several advantages over traditional metal fabrication methods.

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- **Speed** of production and reduced lead times
 - **Flexibility** for complex part geometries, metal sizes and types
 - **Repeatability** for prototype runs and large production volumes
 - **Cost-effectiveness** with tooling and no added cost for number of features or complexity.

- 1 DRAWING REVIEW**
CAD image designed to manufacture with PCM
- 2 METAL CLEANING**
Includes degreasing, acid washing, scrubbing and drying
- 3 COATING**
Photoresist applied to the metal on both sides
- 4 EXPOSING**
Polymerize photoresist to defined areas using UV light
- 5 DEVELOPING**
Dissolve unexposed photoresist, leaving polymerized resist bonded to the metal surface
- 6 ETCHING**
Acid etchant sprayed on both sides of the metal to dissolve features
- 7 STRIPPING**
Alkaline wash removes polymerized photoresist from metal
- 8 VALUE-ADDS**
Secondary services performed to finish parts
- 9 INSPECTION**
Inspected digitally through optical measurement systems as well as manually
- 10 SHIPPING**
Custom packaged and shipped

Material Selection

Selecting the right metal for your part depends on the application. Consider the following when picking a metal for your part.

Corrosion Resistance – Will the metal need to withstand damage caused by oxidation or other chemical reactions in the application environment?

Ductility – Will the metal need to be formed or shaped without breaking?

Tensile Strength – Will the metal need to withstand a certain amount of force before snapping?

Weldability – Will the metal need soldering, and does it require additional preparation, techniques, or tools?

Metal Alloy Temper The etching process doesn't affect the metal temper; it will remain unchanged throughout the process.

Metal Thickness Our etching process can produce your part from sheets of metal ranging in thickness from 0.0002 inches (0.005 mm) up to 0.090 inches (2.286 mm).

Sheet Size Fotofab's standard metal sheet size measures 12 inches x 18 inches (305 mm x 457 mm), with largest capability at 24 x 36 inches. Various sheet sizes are available depending on metal type and availability.

Part Size The overall size of the parts we fabricate can vary from a single part occupying an entire sheet to those yielding several thousand pieces per sheet.



Materials

Photochemical machining can etch a wide range of metals.

- | | | |
|--------------------|------------|-------------------|
| → Aluminum | → Invar | → Nickel-Iron |
| → Beryllium Copper | → Kovar | → Nickel Silver |
| → Brass | → Metglas | → Phosphor Bronze |
| → Bronze | → Monel | → Spring Steel |
| → Copper | → Mu-Metal | → Stainless Steel |
| → Copper-Nickel | → Nichrome | → Steel |
| → Inconel | → Nickel | → Titanium |

If you do not find a metal you need on this list, contact us so we can discuss options.

Design Guidelines

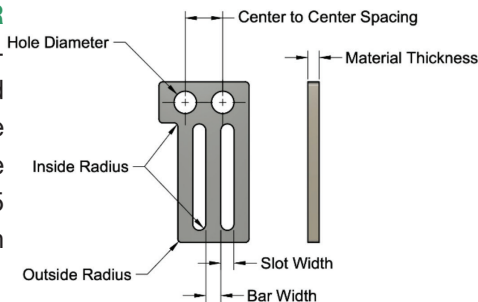
The Fotofab process places no limit on the complexity of your part's configuration. However, there are some limits to the minimum size or tolerance considerations of the etched features in relation to the thickness of the material. The following explanations are general guidelines.

HOLE DIAMETERS AND SLOT WIDTHS: The design layout and metal thickness determine the minimum size of a hole diameter or a slot width. Our process ranges from 90% to 120% of the metal thickness for these features. The minimum practical diameter or slot width is 0.004 inches (0.102 mm).

BAR WIDTHS: The minimum bar width is 90% of the metal thickness. The minimum practical bar width is 0.003 inches (0.076 mm).

CENTER-TO-CENTER TOLERANCES:

Center-to-center accuracy is determined digitally rather than by the etching process. This tolerance is typically within ± 0.0005 inches (0.013 mm) over a span of 6 inches (152 mm).



ETCHED DIMENSIONAL TOLERANCES: The etched dimensional tolerance is affected by metal type, metal thickness, etch type and complexity, use of tabs, and photoresist thickness. Dimensional tolerances for dropout parts also differ from parts that remain in the sheet (see page 10). Typical feature tolerances are $\pm 20\%$ of the metal thickness.

RADIUS - INSIDE AND OUTSIDE: In the photochemical machining process, all corners of a part, whether on an inside or outside edge, will have an associated radius. The minimum inside radius we recommend for a part design is roughly equal to the metal thickness. The minimum outside radius we recommend is 90% of the metal thickness.

CORNER RADII OF A SHARP-CORNERED

Rectangular
Hole as Etched



Rectangular Hole
with Optional
Corner Reliefs

OBJECT: Figure 2 illustrates the difference between the internal radii for an etched rectangle (left) and the same etched rectangle having corner reliefs (right). Etching with internal corner reliefs allows your part features to join with external components or surfaces having 90-degree corners.

CORNER RADII OF A NARROW

LEAD: The Fotofab process is capable of fabricating parts with narrow leads.

Figure 3 illustrates the difference between the external corner radii for an etched lead (left) and the same etched lead having external corner reliefs on each side of the lead (right). Etching with external corner reliefs allows your part features to fit flush against external components or surfaces having a 90-degree corner.

Lead as Etched



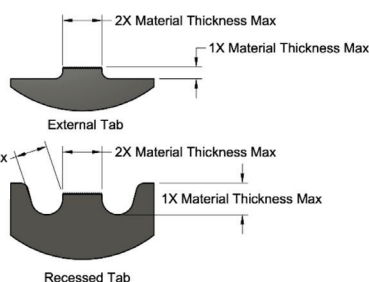
Narrow Lead with
Optional Relief



TABS AND DROPOUT PARTS: To achieve the tightest tolerances, we recommend designing parts to remain in the sheet using tabs. A tab is the small amount of metal that bridges the part to the sheet and allows for safer handling and easier inventory. When a part is detached from the tab, a small metal remnant or inclusions will be left on the part. If your part requires a smooth edge, you can design your part as a dropout (without tabs). Please note that dropout parts don't hold the same tolerances as tabbed parts.

TABS: Fotofab offers two options for tabs: external to the part or recessed into the part. The type of tab you use depends on the edge requirements for your part. After a part is detached from the metal frame, it will have a slight edge equal to the starting metal thickness.

Figure 4 illustrates the general appearance and maximum tab dimensions of an external and recessed tab after being removed from the sheet. For thicker metal parts, a small score line can be etched into one side of either tab type to facilitate the removal from the metal sheet.



DROPOUT PARTS: If your part design cannot accommodate a tab, we can produce the part as a dropout. The method to hold parts in place without tabs adds variation to final feature dimensions and typically requires wider tolerances. Dropout parts are best suited for metal thicknesses greater than 0.010 inches (0.254 mm).

ADDITIONAL ETCHING CAPABILITIES

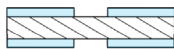
SELECTIVE ETCHING: We can selectively etch your part so that a portion is approximately half the thickness of the original metal sheet. This allows you to etch logos or identification text/numbers onto the surface of your part. Another benefit of selective etching is the ability to add bend (score) lines into your design. Selective etching depths depend on your design and aren't available for thin metals or foils. Fotofab can selectively etch up to 80% of the starting metal thickness for most parts.

BEND CHANNELS: Hand-foldable, etched bend channels are a unique feature that Fotofab can incorporate into your metal part. Of metal thicknesses between 0.008" (0.2 mm) to 0.020" (0.5 mm), a bend channel allows anyone to manually form the sidewalls of the part from a 2D blank to a 3D finished component.

INCORPORATING BEND CHANNELS OFFERS SEVERAL BENEFITS.

1. They allow you to form your part without traditional forming tools, helping you save hundreds of dollars and several days of delivery lead time.
2. They exhibit a zero inside radius when formed, saving space on your board by reducing the clearance between the enclosure and the components within.
3. Typically intended to create 90° right angle bends, they can also

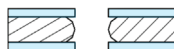
ETCHED PROFILE



Metal with Exposed and Developed Photoresist



Partially Etched Metal



Metal Etched to Nominal Dimensions



Metal Under-Etched in Regard to Nominal Dimensions



Metal Over-Etched in Regard to Nominal Dimensions

Caution: Etched bend channels, formed by removing 50% to 75% of the metal thickness, impact overall strength along the channels. For load-bearing or vibration-prone applications, Fotofab suggests using hard-forming tools for shield blanks instead of bend channels.

REMOVABLE COVERS: Some applications, like shields, may require a cover or removable lid to allow access to other components underneath. We refer to this design option as a “removable lid” or “two-piece” design. The minimum height of an assembled cover with dimples and a fold-down fence is 0.090”.

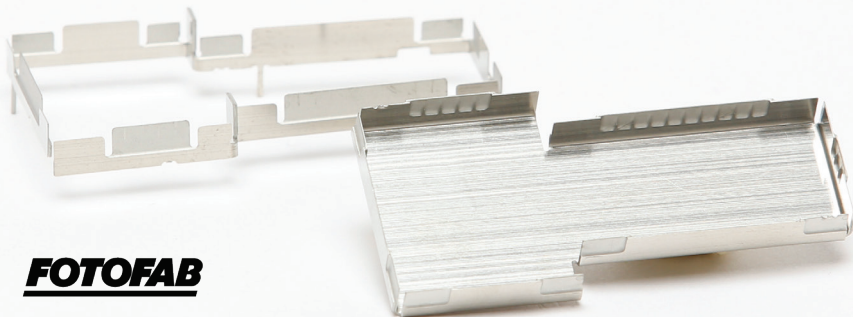
Depending on your design, we can fabricate removable lids with these different mechanical locking or mating methods.

Mating dimples
Mating tabs and slots

Friction fits
Locking spring fingers

INTERNAL WALLS: Some applications may require internal walls or fences that prevent radio frequency interference (RFI) or crosstalk among different regions or components under a larger enclosure. We can make complex “multi-cavity” component enclosures to match your specifications.

RAISED OR ROUNDED FEATURES: Your design may require a part with a unique feature like stepped or domed regions or rounded rather than squared edges or corners. Fotofab can achieve this by combining etching and other metalworking processes.



VALUE-ADDED SERVICES

Fotofab offers additional design, finishing, and value-added services to deliver complete ready-to-use parts.

FORMING AND STAMPING: Fotofab provides a full range of metal bending and forming services on a rapid delivery basis. We manufacture all our own tooling in-house so that we can control quality and lead times. Our system of forming uses simple tooling built quickly and inexpensively. With kick presses, hydraulic presses, a deep draw press, 4-slide machines, stamping machines, and hand forming available, we can produce precision-formed metal to your exact requirements.

Benefits of Fotofab Forming

Speed: Parts can be formed in as little as one day.

Precision: Tolerances can be held as tight as $\pm 0.001''$ (0.025mm).

Cost: Tooling cost is minimal.

Flexibility: Multi-station tooling allows geometries not otherwise achievable with progressive dies.

FINISHING: Fotofab is a full-service provider of high-quality thin metal parts. Through our extensive and vetted partner network, we offer value-added and metal finishing options to bring you closer to the production finish line. We also have custom packaging, from bulk-packed sheets to detached and individually packaged.

Blackening
Services

Diffusion Bonding
Electropolishing

Painting
Passivation
Plating
Reaming

Soldering &
Welding
Tumbling
Wire EDM

COMPONENTS & PRODUCTS: We custom manufacture parts to meet your exact specifications. Examples of metal components we fabricate include:

Encoder Disks and Wheels
Electrical Contacts
Flat Springs
Fuel Cell Plates
Lead Frames

Low-Profile Shields
Masks
Multichambered Shields
Shims and Washers
Surgical Snares

CUSTOM PART DESIGN: Our process is ideal for custom part design and manufacturing. All we need is a drawing to get started. We then leverage resources and develop superior solutions for your application. Our knowledgeable engineering team is adept in design for manufacturability (DFM) and can help you save time and money.

CERTIFICATIONS

Fotofab is committed to exceptional part quality and is a preferred supplier of custom-made precision metal parts to hundreds of industry leaders in aerospace, defense, medical, energy, and electronics. Fotofab maintains certification for various quality, environmental, and defense regulations.



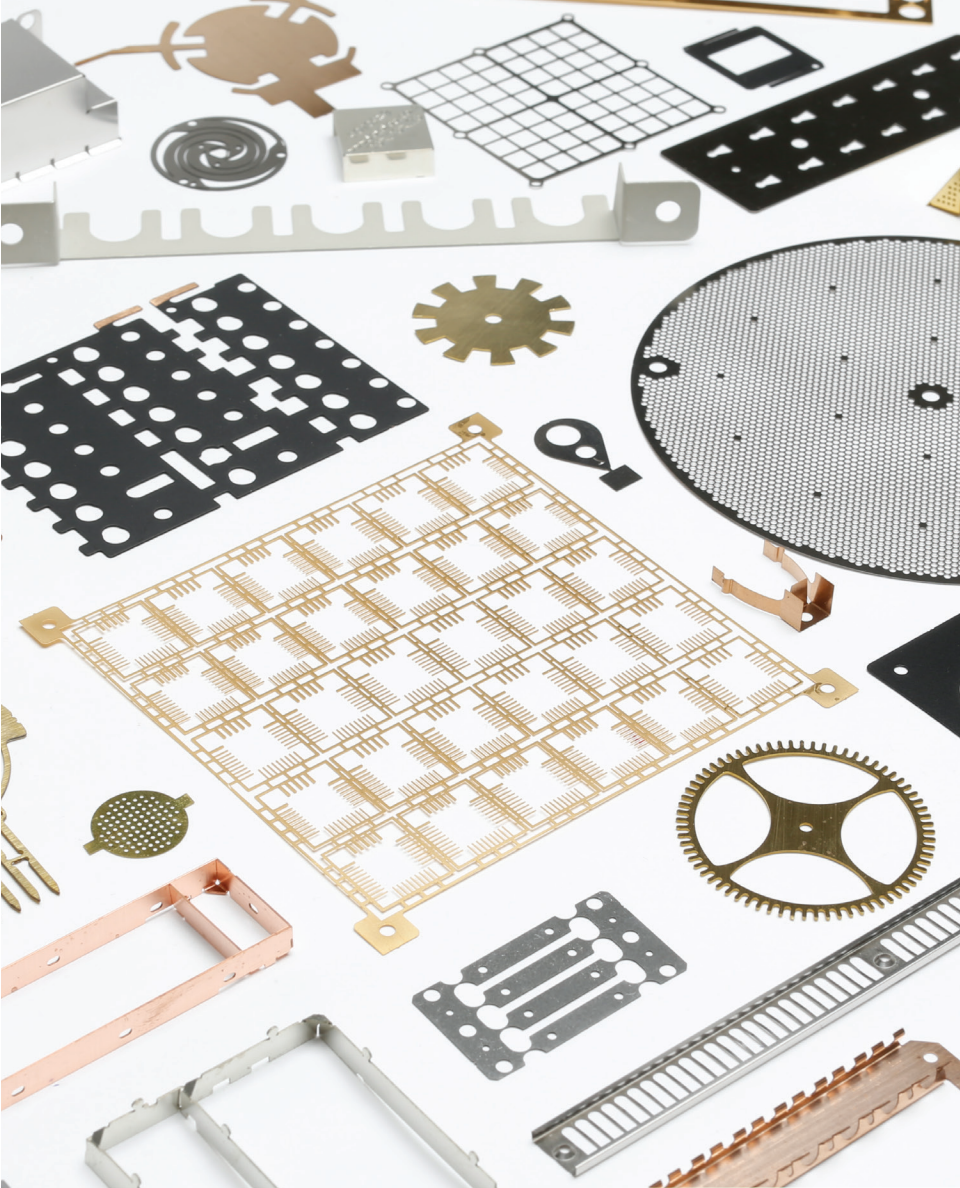
ISO & AS9100D Certified

RoHS Compliant

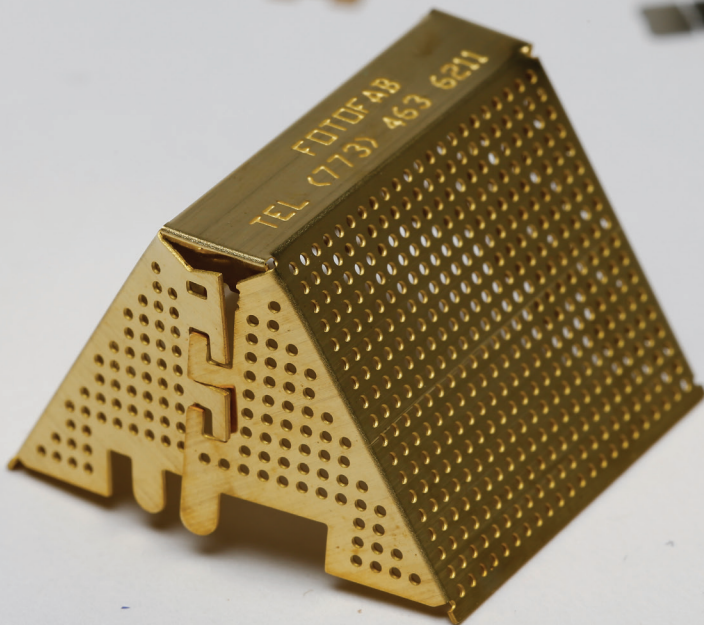


ITAR Registered

Conflict-Free Mineral Policy



FOTOFAB A Part In Your Plan.



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